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ABSTRACT

Project ARCHIMEDES was designed in cooperation with local teachers to enhance concept understanding of teachers of physics and physical sciences, to increase use of electronics and computers in the classroom, and to introduce research on students' misconceptions in physics, teaching methods for identifying and remediating misconceptions, and ways to improve students' problem-solving skills. It consisted of a summer institute for 62 teachers on teaching physical science concepts, an academic-year follow-up, academic-year courses on physics content and problem-solving skills, and a summer institute on practical teaching skills. Participants reported increased conceptual understanding, more awareness of misconceptions, more use of laboratories and demonstrations in the classroom, increased teaching confidence, and increased use of electronics and computers. High school staff have been active in conducting workshops in their school districts to multiply the project's effects. Some forms and materials used in the project are appended. (MSE)

Project ARCHIMEDES: Applications, Reasoning and Concepts for High School Instructors: Making Educational Discoveries and Expanding Skills.

Suzanne M. Lea
Principal Investigator

AASCU/ERIC Model Programs Inventory Project

The AASCU/ERIC Model Programs Inventory is a two-year project seeking to establish and test a model system for collecting and disseminating information on model programs at AASCU-member institutions--375 of the public four-year colleges and universities in the United States.

The four objectives of the project are:

- To increase the information on model programs available to all institutions through the ERIC system
- To encourage the use of the ERIC system by AASCU institutions
- To improve AASCU's ability to know about, and share information on, activities at member institutions, and
- To test a model for collaboration with ERIC that other national organizations might adopt.

The AASCU/ERIC Model Programs Inventory Project is funded with a grant from the Fund for the Improvement of Postsecondary Education to the American Association of State Colleges and Universities, in collaboration with the ERIC Clearinghouse on Higher Education at The George Washington University.

APPENDIX 9

NATIONAL SCIENCE FOUNDATION Washington, D.C. 20550	FINAL PROJECT REPORT NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3 NSF Award Number
University of North Carolina at Greensboro Greensboro, NC 27412	Teacher Preparation & Enhancement	TEI 84-70438 & 87-44574
	4. Award Period From 2/1/85 To 9/30/88	5. Cumulative Award Amount $272,746.00

6. Project Title Project ARCHIMEDES: Applications, Reasoning and Concepts for High School Instructors: Making Educational Discoveries and Expanding Skills

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

The aims of Project ARCHIMEDES were to enhance understanding of physics concepts; to increase use of electronics and computers in the classroom; and to introduce research on students' misconceptions in physics, teaching methods which can assist in diagnosing and remediating the misconceptions, and improving students' problem-solving skills. The project consisted of a summer institute on Teaching Physical Science Concepts, an academic-year follow-up, academic-year courses on physics content and problem-solving skills (funded entirely by UNCG) and a summer institute on Practical Skills for Teachers (funded in part by local school districts). The Concepts Institute used materials developed by McDermott et al. based on their misconceptions research at the University of Washington, Seattle.

62 teachers participated in the activities. Participants (including elementary teachers) in the project activities report increased conceptual understanding, more awareness of misconceptions, more use of laboratories and demonstrations in the classroom, increased confidence in teaching physics and/or physical science, and increased use of electronics and computers in the classroom. Highschool staff have been active in conducting workshops in their school districts to multiply the effect of the project. Participants and staff agree that the project has been very successful and forms an excellent model for other such programs.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses	X				
b. Publication Citations		X			
c. Data on Scientific Collaborators	X				
d. Information on Inventions	X				
e. Technical Description of Project and Results		X			
f. Other *(specify)*	[redacted]				

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Suzanne M. Lea	Suzanne M Lea	12-2-88

I. INTRODUCTION

Project ARCHIMEDES (TEI 84-70438, supplemental grant 87-44574) was designed in cooperation with local teachers to enhance the preparation and background of in-service teachers of physics and/or physical science. A summer institute on teaching physics and physical science concepts (the Concepts Institute) used hands-on materials to improve understanding of fundamental concepts and to develop teaching methods to help overcome student misconceptions (alternative conceptions) about physics. An in-service follow-up course during the academic year (the Follow-up) helped participants apply the teaching methods in their classrooms, introduced them to current research on student misconceptions, and provided tours of local industries and lecturers on recent developments in physics. Problem-solving skills courses during the academic year provided additional background in content areas and an introduction to research on improving students' problem-solving skills. A summer institute on practical skills for teachers (the Skills Institute) taught skills in electronics, the use of electrical laboratory equipment, and the use of microcomputers in participants' courses.

The activities were designed for 20 participants each. The problem-solving courses were funded entirely by the University of North Carolina at Greensboro. The Skills Institutes were partially funded by local school systems. An attempt was made to obtain microcomputers from IBM Corporation for use in the Skills Institute. The attempt (discussed in more detail below) was not successful.

The cycle of activities was offered twice (summer, 1985, through summer, 1986, and summer, 1986, through summer, 1987), with participants from the first Concepts Institute helping teach the second Concepts Institute. Demand from local teachers and the generosity of the National Science Foundation in providing a supplementary grant enabled us to hold the Concepts Institute a third time, during the summer of 1987, and to include elementary school teachers as participants. A participant from the first Concepts Institute helped teach the third Concepts Institute.

Project ARCHIMEDES was designed to enhance the preparation of persons presently teaching physics and/or physical science. Naturally, we would prefer to have persons with a degree in physics teaching these subjects. However, the realities of the public school system in North Carolina and the career goals of physics majors make it unlikely that this aim will be achieved in the near future. First, most persons teaching physics in North Carolina teach one physics course and 3 to 4 other courses. Certification requires that the majority of their subject matter hours must be in the field they teach more than half time. Further, very few physics majors are interested in careers in high school teaching. Second, North Carolina has a tenure law for public school teachers. As a consequence, principals will assign a tenured teacher to teach out of field rather than hire a new teacher in the field. Given this situation, we feel that projects such as ARCHIMEDES present a valid response to concerns about the quality of pre-college science teaching.

II. PARTICIPANTS

Project ARCHIMEDES was designed for participants selected from North Carolina Education Region V, an 11-county area centered on Greensboro. All participants commuted. Commuting distances ranged from 2 blocks to 68 miles one

way.

Participants were selected on the basis of applications which included a letter of recommendation from the principal or science supervisor and a statement of why the applicant needed the activities. Participants were required to commit themselves to take part in all portions of the activity they applied for. (Participants in the Concepts Institute were required to participate in the Follow-up. The Problem-solving courses and the Skills Institute were treated as separate activities.) There were 66 total applicants and 62 total participants. Of these, 23 were white male, 33 white female, 2 black male, 3 black female, and 1 Asian female. Table 1 gives details of the participants' backgrounds and teaching level.

Table 1. Participants in Project ARCHIMEDES

academic years:	1985-6	1986-7	1987-8	total
Concepts Institute (summer)	20*	23*	15*	58
Follow-up (academic year)	19	22	-	41
Problem-solving Courses (academic year)				
Physics 501a, 501b (conceptual)	2,6	6,7	-	8,13
Physics 601a, 601b (algebra-based)	8,10	3,-	-	11,10
Physics 605a, 605b (calculus-based)	-	16,16	3,5	19,21
Skills Institute (summer)	-	13	15	28
High-school teachers[a]	16	22	22	60
Middle-school/junior-high teachers[a]	4	14	14	32
Elementary-school teachers	-	-	3*	3
Degree:[b] Physics/Physics Education	2	1	-	3
Chemistry/Chemistry Education	6	2	3	11
Mathematics/Mathematics Education	1	1	1	3
Biology/Biology Education	6	7	4	17
Science/Science Education	-	5	4	9
Other[c]	5	7	7	19

*One participant dropped out.
[a]Some participants are counted twice here.
[b]Participants are not counted twice here.
[c]Other includes the following fields (number of persons in parentheses): Political Science (1), Social Science (3), Pre-med (1), Health & PE (3), Education (not science) (6), Home Economics (2), English (1), Accounting (1), Theology (1)

It should be noted that all participants are presently teaching physics and/or physical science, or were scheduled to teach it during the following school year, with the exception of the two elementary teachers (discussed below). The participants were self-selected in the sense that they care enough about excellence in teaching to apply to ARCHIMEDES. We were impressed by the ability, perseverance, and interest of our participants.

Participants could earn up to 20 hours of graduate credit in physics through attendance at the activities of Project ARCHIMEDES. Many of the participants elected to complete a master's degree, either the M. Ed. in Physics (offered through the physics department) or the M. Ed. in Science Education (offered through the School of Education). Both degrees require a comprehensive examination. The M. Ed. in Physics requires 33 hours, of which at least 24 must be in physics. The physics hours must include calculus-based physics. Fifteen of the participants enrolled in this program; five have obtained their degrees.

The M. Ed. in Science Education requires 33 hours, of which at least 18 must be in a subject matter field. Seven of the participants enrolled in this program; two have obtained their degrees. In addition, one participant is enrolled in a program leading to the Ed. D. degree, and one participant has received a Certificate of Advanced Study in Education (30 semester hours past the master's degree).

III. ADMINISTRATIVE ORGANIZATION OF ACTIVITIES

All activities used existing course numbers in the Department of Physics and Astronomy and were scheduled through the Office of Continuing Education of the University of North Carolina at Greensboro. The staff of the Office of Continuing Education were very helpful; without them, the administration of the grant would not have run so smoothly. An accountant handled paperwork associated with the expenditure of grant funds, relieving the academic staff of the burden of such details. A coordinator handled scheduling of activities, reporting of grades, appointment of high-school staff to the adjunct faculty, and other administrative details.

Because activities were scheduled through Continuing Education, an exemption from the University policy which limits the number of hours of Continuing Education courses which may be applied to a degree was required. However, using existing course numbers and teaching the courses with regular faculty on campus meant that the exemption was granted routinely.

The Concepts Institute met 5 hours/day for 6 weeks in summer, 1985 and 1986, and 5 hours/day for 5 weeks in summer, 1987. The Skills Institute met 5 hours/day for 6 weeks in summer, 1986 and 1987. Each institute carried 6 hours of graduate credit in physics. The academic-year Follow-up met 2 hours/week for 15 weeks in 1985-1986 and 1986-1987. It carried 2 hours of graduate credit in physics. The Problem-solving Courses met 3 hours/week for 30 weeks during 1985-1986 and 1986-1987. They carried 6 graduate credit hours in physics each.

We attempted to secure a donation of microcomputers, peripherals, and software for the Skills Institutes. The equipment was to return with the participants to their classrooms on permanent loan at the end of the institute. Tandy, Apple, and Commodore do not consider proposals of such size (40 systems). IBM was very interested in the proposal; a corporate representative from University Relations spent a full day observing activities in summer, 1985, and provided suggestions about the form and content of the proposal. Unfortunately, unknown to either us or IBM's Office of University Relations, our proposal fell in the category of pre-college education, because the microcomputers ultimately went to participants' classrooms. IBM's policy for pre-college proposals in North Carolina is to make donations only through the state's Mathematics and Science Education Network. We were unsuccessful in trying to obtain Network sponsorship of our proposal. The lack of a grant of computers did not affect the Skills Institute, since all participants were able to bring computers to the Institute. Most participants borrowed computer systems from their school districts.

No administrative problems were encountered other than the failure to obtain a donation of microcomputer systems and software. Occasional conflicts between school-mandated activities and the project activities were handled by a little flexibility on all sides. Generally, principals of participants were enthusiastic and supportive of project activities. They gladly provided the $250.00 school-system contribution toward equipment for the Skills Institute. We do plan, in future activities, to provide mechanisms for keeping principals

informed and encouraging their support of participants.

IV. PROJECT ACTIVITIES AND IMPACT

A. Publicity

Project activities were publicized through news releases, direct mail, word of mouth, and presentations at professional meetings. Copies of the brochure and application forms used in the direct mailing are in Appendix I. A copy of this brochure and application was mailed each spring to every physics and physical science teacher in Region V. Names and addresses were supplied by the State Department of Public Instruction.

The principal investigator was invited to present a paper on student misconceptions at The Christmas Conference on Recent Advances in Physics, 1986. The Christmas Conference, sponsored by the Physics Department of the University of North Carolina at Chapel Hill and by the State Department of Public Instruction, is held annually in late December to update the physics background of high-school, community-college, and small-college physics teachers. In addition, the principal investigator and the co-principal investigators contributed papers to professional meetings. A list of papers presented is in Appendix II. Two articles on the project and its impact are being prepared and will be submitted to **The American Journal of Physics**. Copies are attached in Appendix III.

The selection of participants was accompanied by a news release to their local newspaper. Responses ranged from not printing the release at all to a full-page article with picture on the front of the second section. The size of the response seemed to be an inverse function of the size of the community served by the paper.

The principal and co-principal investigators have responded to approximately 10 written requests for information about the project, as well as numerous oral requests.

B. Attitudes

It was felt to be important that participants and staff interact in a relaxed and informal atmosphere. Further, since most participants came directly from school to the institutes during the summer, a six-weeks-long institute has great potential for participant "burnout". To assist in developing a relaxed atmosphere, preventing burnout, and inducing a positive attitude, several social activities were held for the participants and staff each summer.

Each summer, an introductory social with refreshments was held the first day of the institutes. Funds for the social were provided by the Office of the Dean of the College of Arts and Sciences in 1985 and 1986, and by the Department of Physics and Astronomy in 1987. An end-of-institute party was held on the afternoon of the last day of the institutes. Funds for this activity were provided by the participants and staff.

During the institutes, occasional communal pizza-lunches were held. Coffee-break during the morning was enforced, since participants would work straight through if not reminded to take the break. Participants sometimes provided edible "goodies" for colleagues and staff during this break. In addition, each summer a directory of participants and staff (name, school and home address and telephone) was distributed to all participants and staff in each institute. The directory helped the staff enormously in getting in touch with participants during the academic year; it also enabled participants to get in touch with each

other easily.

Finally, the staff tried very hard to set up an informal and non-threatening class atmosphere, where everybody was on a first-name basis. The hands-on nature of the materials used in the institutes and consequent paucity of formal lectures helped immeasurably in developing this atmosphere, which persisted into the problem-solving courses (where lectures were somewhat more frequent).

On the whole, observation of and evaluation by the participants revealed a positive final attitude toward both physics and the project activities. In some cases, this attitude was a reversal of the participant's initial attitude. In our opinion, the social activities and the attempts to create informal class atmospheres provided positive attitudinal changes and/or reinforcements. We hope the teachers will transmit their positive attitudes to their students. Given the negative attitude toward physics prevalent among many pre-college students and some teachers, the changes in attitude assume great importance.

It should be noted that the principal investigator is a female physicist, and was a member of the faculty of the Department of Physics and Astronomy at the time the project activities occurred. She was part of the staff for the Concepts Institute each time it was offered. For most of the participants, the Concepts Institute formed the introduction to the project. It is not known, and should be investigated, whether the presence of a female physicist as part of the staff improves atmosphere and attitude in institutes. The presence of a female physicist on the staff was, in our case, not the sole factor determining participants' attitudes, as shown by the persistence of positive attitudes through the activities of the Follow-ups, and Skills Institutes, which she did not teach.

C. The Concepts Institute

The aims of the Concepts Institute were to enhance participants' understanding of basic physics concepts, to introduce participants to results of research on student misconceptions in physics, and to introduce teaching methods which can help overcome student misconceptions. To achieve these aims, materials developed by the Physics Education Research Group at the University of Washington, Seattle, under the direction of Prof. L. C. McDermott, were used. The staff also used the teaching methods found by this group to work well with their materials; these methods consist of hands-on experiments to develop concepts, Socratic dialogue between staff and participants (answering questions with questions), and occasional group discussions of concepts. Formal lectures were not used.

The Concepts Institute was evaluated by the participants, the highschool staff who helped teach it in 1986 and 1987, and the university staff who taught it all three summers. The highschool staff had participated in the Concepts Institute in 1985. The staff evaluations consider the Institute to have been successful and the materials to have worked well. Within a grade range of A, B, C, D, F, the staff gave the materials and Institute average grades of B+ and A.

There were 4 participants (of 56 total) who did not respond positively to the materials and methods used. In two cases, the participants felt that the materials were too elementary; however, they did not exhibit a high level of conceptual understanding on tests. In the other two cases, the response seems to be related to learning style: both these participants seemed to have been successful in past learning situations by using skill in memorization. Comments indicated they were very uncomfortable with materials and methods which required understanding and reasoning. ("Tests that are given should cover things that are

actually covered rather than things that can be vaguely related." "The concepts were not taught, which did not help me at all in understanding what I was supposed to have discovered.")

The Concepts Institute also served as a field test of the materials developed at the University of Washington. Four modules were used: **Properties of Matter**, **Kinematics**, **Heat and Temperature**, and **Electric Circuits**. The first two modules had been extensively field-tested previously and were used unchanged during all three summers. Participant evaluations of these modules give some idea of the variability of groups from summer to summer. The latter two were revised before the summer of 1986; **Electric Circuits** was revised a second time prior to the summer of 1987. Participant evaluations of these modules, weighted by the variability indicated in evaluations of the first two modules, give an estimate of the improvement in the modules. Table 2 gives participant evaluations of the Concepts Institute and of the modules.

It is obvious from the table that, as far as the participants were concerned, **Heat and Temperature** was improved by its revision prior to 1986, and **Electric Circuits** was improved by its revisions, in particular the second revision. It should be noted that part of the negative response to **Electric Circuits** is caused by the difficulty many participants had in coping with the batteries and bulbs equipment.

Participants were asked a number of questions designed to find out whether they felt the Concepts Institute had been useful to them. Only two of the 56 participants indicated that it had not been useful.

Participants were asked to explain why they had given the Institute, the materials, and the staff the grades they did, and to make any other comments they

Table 2. Evaluation by Participants of Concepts Institute and Materials

Grade	Concepts Institute	Properties of Matter	Kine-matics	Heat and Temperature	Electric Circuits
A ('85)	15 (75%)	11 (55%)	11 (55%)	5 (25%)	10 (50%)
B ('85)	5 (25%)	7 (35%)	5 (25%)	12 (60%)	5 (25%)
C ('85)	-	1 (5%)	2 (10%)	2 (10%)	2 (10%)
A ('86)	10 (45%)	13 (59%)	11 (50%)	10 (45%)	3 (14%)
B ('86)	9 (41%)	5 (23%)	6 (27%)	6 (27%)	9 (41%)
C ('86)	1 (5%)	3 (14%)	2 (9%)	3 (14%)	7 (32%)
D ('86)	1 (5%)	-	1 (5%)	2 (9%)	1 (5%)
F ('86)	-	-	-	-	1 (5%)
A ('87)	12 (86%)	11 (79%)	5 (36%)	6 (43%)	9 (64%)
B ('87)	2 (14%)	2 (14%)	8 (57%)	5 (36%)	5 (36%)
C ('87)	-	1 (7%)	1 (7%)	2 (14%)	-
D ('87)	-	-	-	1 (7%)	-

felt inclined to. The pattern of comments over all 3 summers reveals an interesting emphasis on how much they had learned and the increase in their confidence. Representative comments are given below.

(1985)

"I never knew a college course could be so much fun."

"I have learned an awful lot. I also found out some of my own weaknesses."

"I would like to finish working in all of these modules in the future."

"I have some trouble with some of the concepts we covered."

(1986)

"Roses are red, violets are pink. Wonder of wonders, physics don't stink!" [This comment was signed; it originated with the participant whose undergraduate major had been English.]

"I have enjoyed and learned more in this course than any [other] I have ever taken."

"I still feel unsure of my experience and knowledge in these areas--but when I teach this material I will have a good background to start with."

"I have grasped an understanding of many concepts--some for the very first time."

"I enjoyed learning by discovering for myself."

(1987)

"The course exposed weak areas that need to be strengthened."

"The Concepts Institute has provided me an opportunity to work through various experiments in order to reach a higher level of understanding. I value this understanding because it will give me a broader perspective and confidence to teach Science."

"It has given me confidence in areas that I was unsure in, and I know will help me to answer my students' questions."

"This course ... has helped me more with the fundamentals of physics than anything [else] I have participated in."

"At first, I didn't really think I was going to like all the labs I had to complete. However, I have gotten more out of this science course than I have for all the others I have taken."

In summary, it appears that participants feel (on the whole) that they have improved their understanding; that they feel more confident about teaching physics and/or physical science; that they enjoyed the conceptually oriented, hands-on approach without lectures; and that the Institute will be useful to them in their own classroom teaching.

The Concepts Institute in 1987 included for the first time elementary school teachers as participants. The supplementary grant provided funds to enable an investigation of how elementary teachers understand basic physics concepts taught in standard highschool physics courses and how they diagnose and correct their students' preconceptions and misconceptions. In addition, the question of how elementary teachers respond in an instructional setting where middle school and highschool teachers are also present was investigated.

One of the elementary school teachers dropped out after the first day because she had an offer to teach summer school in a system where she would like to be employed full time. Two other elementary teachers completed the Concepts Institute. Both of these teachers were enrolled in a program leading to the M. Ed. in Elementary Science Education degree. In that sense, they are not representative of all elementary teachers.

Neither of these teachers felt that her background in physical science from highschool or undergraduate education was strong. One of the teachers had never had algebra, either in highschool or in college. Both teachers exhibited many of the standard misconceptions found in beginning physics students. Neither teacher was aware of recent research on misconceptions in physics until enrolling in a course taught by the principal investigator during the 1986-1987 academic year. Both were enthusiastic about learning more, both in the area of content and in the area of methods to diagnose and overcome misconceptions. Both teachers improved their understanding of basic physics concepts, which was initially poor, by enormous amounts during the course of the Concepts Institute. Both also

became convinced of the value of hands-on activities to diagnose and help remediate misconceptions. The principal investigator contributed questions to the comprehensive examinations they took for their degrees. Both had retained their content knowledge and ability to use hands-on activities to diagnose and remediate misconceptions to that point.

It was considered possible that mixing highschool, middle school, and elementary teachers in the same class might be deleterious to the elementary or middle school teachers from the point of view of improving their confidence and skills. This effect did not occur; in fact, the elementary and middle school teachers were completely willing to argue their points of view without any signs of deference to (presumably) more expert highschool teachers. This result confirms for in-service teachers the result of McDermott with pre-service teachers, that mixing pre-service elementary and highschool teachers in an instructional setting does not adversely affect the class participation or self-image of the elementary teachers.

The elementary teachers were asked to fill out a special evaluation form in addition to the standard form. Both indicated that, while the concepts covered were not identical to the ones they would be teaching, the Concepts Institute had been very useful to them personally. Asked to select the most difficult topic, one responded kinematics, and the other (the one who had never had algebra), the type of reasoning used in problems. The confidence level of these teachers increased, as is indicated by their comments.

"I feel more confident in being able to develop and teach science with activities."

"I did learn a great deal once I understood, and it is firmly planted in my mind.... There were several ideas I had wrong; now I know the correct answers. I will not have to be afraid of a kid that has learned more than me or asking a simple question I can't answer."

D. The Follow-up

The participants in the Concepts Institutes were required to enroll in the two-semester, academic year Follow-up. All of them did so. The 1985-86 and 1986-87 Follow-ups were conducted by the co-principal investigators Muir and Hageseth. There were six meetings and one site visit each semester. The meetings included classroom work (two hour sessions) and field trips which varied in duration.

Some of the classroom sessions were used to continue work from the summer Concepts Institute, e.g., studying the properties of waves using the materials developed at the University of Washington. Some of the classroom sessions dealt with topics of interest arrived at by consensus of the group. One of these topics was spectroscopy (using diffraction gratings, meter sticks, and line source discharge tubes). Another was the use of electronic equipment in the lab. An experiment to measure the velocity of sound using travelling waves illustrated the use of a signal generator, amplifier, and oscilloscope.

Each participant was visited in his/her classroom once each semester. Each participant was visited once by each of the instructors. During these site visits, the instructors became better acquainted with the participants, learned about their particular teaching settings, and met their principals and some of their colleagues (some of whom subsequently became ARCHIMEDES participants). The participants were able to obtain advice on topics of specific interest to them, such as: what was the function and purpose of certain pieces of equipment they had inherited, what are appropriate priorities in the use of their limited

total enrollments of 12 and 10 in 1985-1986. Ten and 8 of these students were participants from the Concepts Institute in summer, 1985. This course is designed to enhance background in physics content for highschool and community college teachers of physics. In addition to covering standard introductory physics content, the courses introduced participants to research on student misconceptions published in **The American Journal of Physics** and to a selection of readings in and discussions of current research on improving students' problem-solving skills. With two exceptions, the mathematical skills of the participants were sufficient to enable them to solve standard physics problems. Those with insufficient mathematical skills were advised to review algebra and given extra tutoring. Both conceptual understanding and problem-solving skills were emphasized in the assignments and tests. Participants evaluated all parts of the course as useful.

The conceptual physics courses, Physics 501a and 501b, had a total enrollments of 9 and 13 in 1986-1987. Six and 7 of these students were participants from the summer institutes of Project ARCHIMEDES. The courses emphasized conceptual understanding and reasoning about physical questions. A hands-on approach to studying physics and physical science was emphasized. In addition, students were asked to discuss how topics might be adapted for their classes and to react to various physics-related news items (e.g., an advertisement claiming that a heat pump uses no fuel). Participants evaluated the course as interesting and relevant to their classroom work.

The algebra-based problem-solving skills courses, Physics 601a and 601b, had a total enrollment of 4 and 0 in 1986-1987. Three of the 4 in the fall were participants from Project ARCHIMEDES. The approach was similar to that of 1985-1986. We attribute the smaller enrollment to the fact that the 1986 Concepts Institute had a higher number of middle school teachers, who are more likely to take 501a and 501b, and fewer highschool teachers. (In 1985, the Concepts Institute had 4 middle school teachers of 20 participants. In 1986, the number was 11 of 22 participants.)

The calculus-based physics courses, Physics 605a and 605b, had a total enrollment of 16 and 16 in 1986-1987. Fifteen of these were participants in Project ARCHIMEDES. All sixteen were working toward the M. Ed. in Physics degree. The course emphasized formal procedures used in solving problems, since the participants had previously seen the usual introductory physics demonstrations and had been involved extensively in hands-on learning experiences. This course is required for the M. Ed. degree, since holders of the degree frequently are assigned to teach Advanced Placement courses in physics. Participants evaluated the course as demanding, because of the large number of problems assigned, but as one of the most useful they had taken in terms of extending their knowledge and problem-solving skills.

The calculus-based physics courses, Physics 605a and 605b, had a total enrollment of 3 and 5 in 1987-1988. Three of these were participants in Project ARCHIMEDES. No attempt was made to compare the performance of the students in this course to the students in the sophomore course as was done the previous year. The ARCHIMEDES participants did very well in the course. The exhibited a high level of interest in concepts and demonstrated excellent problem solving skills.

F. The Skills Institute

The institute went well both summers. The schedule presented in the grant proposal turned out to be somewhat ambitious. The actual schedule was adapted to

the interests of the participants. About 90% of the topics on the original schedule were covered. A little more time was spent on word processing and spreadsheet applications than had been originally planned. As a consequence, there was no work with integrated circuit analog to digital converters (A-to-D) the first summer. The second summer each participant used an A-to-D circuit wired on a breadboard to digitize the signal from a signal generator and display the resulting data as a waveform on the computer screen. However, not enough time was spent to allow the participants to become proficient enough and confident enough that they can be expected to use the integrated circuit A-to-D in their classes. It is believed that they learned enough about the Apple gameport to use it for interfacing data acquisition projects in their classrooms.

The participants became proficient in breadboarding circuits, and in the use of electronic meters and the oscilloscope. Participants in 1986-1987 received an oscilloscope on permanent loan to take back to their classrooms. The oscilloscopes were donated by the Department of Physics and Astronomy at UNCG. Unfortunately, lack of funds prevented the Department from repeating the donation in 1987-1988.

The format for the institute was almost entirely hands-on laboratory activities in the areas of electronics and computers, with very few lectures. The materials provided by the grant to the participants were supplemented by an extensive set of notes on electronics and digital circuits written by one of the co-principal investigators (Muir). The hands-on format, combined with specific notes on activities and general reference materials on electronics, digital circuits, and computers, worked very well.

Table 3 shows results of participant evaluation of the Skills Institute. The participants' evaluation at the end of each institute gave the institute a grade of A-. A majority of the participants indicated that their understanding of and confidence in the use of hand tools, shop tools, electronics, and computers had increased by large amounts. Very few said that there had been little or no improvement in their understanding and confidence (Some of the participants who indicate little or no improvement in skills areas were already proficient in these areas.)

In their response to a survey in January, 1988 (one semester after the last institute), most of the participants still felt they had made significant improvement in their knowledge and use of tools, electronic instruments, integrated circuits, electric components, productivity software, BASIC, and interfacing sensors with the APPLE gameport. Most participants indicated that they had used or expected to use in their classes multimeters, oscilloscopes, temperature sensors, photodetectors, productivity software, and programs they have written, as well as the power supply, amplifier, signal generator, and breadboarding unit provided by the grant.

The attitude of the participants toward the Skills Institute was very positive, as is indicated by the following comments:

" Thanks for a very productive and useful 6 weeks! I am very glad to have taken this course."

"I will feel more confident in directing my own labs--maybe trying some things I wouldn't have before."

"This course was a real adventure into the unknown for me. I learned a lot and am determined to learn a lot more. I gained the optimism and courage needed to pursue electronic and computer studies."

"I haven't worked harder at anything than I have for this course in a long time, yet I have really enjoyed learning so much. It was nice to get paid for

TABLE 3. Evaluation by Participants of Skills Institu[illegible]

Item					
Grade of Course	('86)	A 9 (69%)	B 4 (31%)		
	('87)	A 12 (80%)	B 3 (20%)		
Relevant topics	('86)	MOST 7 (54%)	SOME 5 (38%)	FEW 1 (8%)	NONE 0 (0%)
	('87)	10 (67%)	3 (20%)	1 (7%)	
Improved understanding of:		A LOT	SOME	LITTLE	NONE
electronics	('86)	12 (92%)	1 (8%)	0 (0%)	0 (0%)
	('87)	14 (93%)	1 (7%)	0 (0%)	0 (0%)
computers	('86)	10 (77%)	3 (23%)	0 (0%)	0 (0%)
	('87)	12 (80%)	3 (20%)	0 (0%)	0 (0%)
use of shop tools	('86)	8 (62%)	5 (38%)	0 (0%)	0 (0%)
	('87)	7 (47%)	5 (33%)	1 (7%)	2 (13%)
use of hand tools	('86)	8 (62%)	4 (31%)	1 (8%)	0 (0%)
	('87)	3 (20%)	9 (60%)	1 (7%)	2 (13%)
Improved confidence in using:					
electronics	('86)	11 (85%)	2 (15%)	0 (0%)	0 (0%)
	('87)	14 (93%)	1 (7%)	0 (0%)	0 (0%)
computers	('86)	9 (69%)	4 (31%)	0 (0%)	0 (0%)
	('87)	11 (73%)	3 (20%)	1 (7%)	0 (0%)
shop tools	('86)	5 (38%)	7 (54%)	1 (8%)	0 (0%)
	('87)	4 (27%)	8 (53%)	1 (7%)	2 (13%)
hand tools	('86)	6 (46%)	5 (38%)	2 (15%)	0 (0%)
	('87)	3 (20%)	7 (47%)	2 (13%)	2 (13%)

Degree participant felt that course objectives were met:

OBJECTIVE*		>90%	70 to 90%	50 to 70%	<50%
1	('86)	12 (92%)	1 (8%)	0 (0%)	0 (0%)
	('87)	9 (60%)	5 (33%)	0 (0%)	1 (7%)
2	('86)	7 (54%)	5 (38%)	2 (15%)	0 (0%)
	('87)	6 (40%)	9 (60%)	0 (0%)	0 (0%)
3	('86)	4 (31%)	7 (54%)	2 (15%)	0 (0%)
	('87)	9 (60%)	4 (27%)	2 (13%)	0 (0%)
4	('86)	4 (31%)	9 (69%)	0 (0%)	0 (0%)
	('87)	6 (40%)	5 (33%)	3 (20%)	1 (7%)
5	('86)	5 (38%)	6 (46%)	2 (15%)	0 (0%)
	('87)	9 (60%)	3 (20%)	3 (20%)	0 (0%)
6	('86)	6 (46%)	5 (38%)	1 (8%)	1 (8%)
	('87)	6 (40%)	7 (47%)	1 (7%)	1 (7%)
7	('86)	11 (85%)	2 (15%)	0 (0%)	0 (0%)
	('87)	10 (67%)	3 (20%)	2 (13%)	0 (0%)
8	('86)	4 (31%)	6 (46%)	3 (23%)	0 (0%)
	('87)	4 (27%)	10 (67%)	0 (0%)	1 (7%)
9	('86)	4 (31%)	6 (46%)	3 (23%)	0 (0%)
	('87)	4 (27%)	10 (67%)	0 (0%)	1 (7%)
10	('86)	6 (46%)	6 (46%)	1 (8%)	0 (0%)
	('87)	7 (47%)	7 (47%)	0 (0%)	1 (7%)
11	('86)	8 (62%)	3 (23%)	2 (15%)	0 (0%)
	('87)	5 (33%)	9 (60%)	1 (7%)	0 (0%)
12	('86)	6 (46%)	7 (54%)	0 (0%)	0 (0%)
	('87)	2 (13%)	8 (53%)	2 (13%)	2 (13%)
13	('86)	11 (85%)	2 (15%)	0 (0%)	0 (0%)
	('87)	6 (40%)	5 (33%)	1 (7%)	2 (13%)

Table 3. (cont)

*The objectives were:

1. Use common hand tools to construct a piece of equipment from scratch.
2. Learn the functions of basic logic integrated circuits.
3. Use logic circuits in applications.
4. Learn to use transducers (thermistor, photodetectors, potentiometers, loudspeakers, etc.)
5. Learn to use operational amplifiers.
6. Learn to about the design and construction of a microcomputer.
7. Learn to use word processor, data base management, and spreadsheet software.
8. Learn how to develop algorithms from a problem statement.
9. Learn how to translate an algorithm into a program.
10. Learn the common, fundamental features of the language BASIC.
11. Learn some fundamentals of data analysis and of computer graphics applications.
12. Learn to interface simple devices (switches, relays, photodetectors, temperature sensors, position sensors) to a microcomputer.
13. Learn about computer peripheral device (printer, disk drive, monitor) communications, interfacing, and standards.

this, but this is the kind of course I would pay to take!"

"This course was more fun than a county fair!"

"This course should be available to all physics teachers! I have never had a more useful course....I plan to provide the opportunity for students to have time for electronics in my basic physics course."

"I knew very little about electronics and almost nothing about computers. I feel that I have learned a lot about the basic concepts of both. I feel confident enough in both now to continue working and improving my skills."

"Wish I had been able to do this when I was 14--I have had questions answered in this course that date back that far!"

Based on the experience gained in offering the Skills Institute, the co-principal investigators make the following recommendations regarding summer institutes of this type:

RECOMMENDATIONS

The institute met for 5 hours/day and 5 days/week for the six weeks (150 contact hours). It is believed that this schedule is a little too exhausting for the participants. However, it is also believed that extensive involvement with hands on activities is a very effective setting for learning the kind of material dealt with in the institute. A format such as this allows participants to leave circuits, experiments, and projects set up from one session to another, a feature that is very difficult to provide during in-service programs. Therefore,
IT IS RECOMMENDED that a summer institute, or workshop, use a schedule within the ranges:

A. 3 hrs/day, 5 days/wk, for 5 or 6 weeks (75 to 90 hrs total);

B. 5 hrs/day, 5 days/wk, for 3 to 5 weeks (60 to 125 hrs total);

if it is to deal with the same content as the Skills Institute of Project ARCHIMEDES.

The evaluation carried out in January, 1988 (three teaching semesters after the 1986 institute and one semester after the 1987 institute) validates the choice of content and activities of the institute. It also indicates that more

time should have been spent on almost every topic. The following indicates highly appropriate subjects and suggested amounts of time required to deal with them effectively if working with teachers having backgrounds similar to the ones involved in Project ARCHIMEDES.

IT IS RECOMMENDED that institutes, or extensive workshops, be provided for teachers of middle and high school science which deal with the subjects:

A. use of computers
   1. productivity software (word processor, database management, spreadsheet, gradebook, etc.). About 30 hours of hands on work resulting in something each teacher will take home and use.
   2. instructional software. A few good "canned" programs that they really learn to use effectively and programs that the participants write themselves (this will require teaching many of them a language [their first language should be one that is easy to learn, e.g., BASIC]). About 40 hours.
   3. laboratory applications including simulations (canned and participant written) (about 20 hours), data acquisition (canned and participant written) including analog to digital conversion (about 20 hours), and methods of data analysis (again, canned and participant written) including graphic presentation, statistical analysis, finding maxima and minima, areas under curves, etc.(about 20 hours).

B. electronics
   1. basic DC & AC circuits, properties of electrical signals and waveforms, use of meters and the oscilloscope. This is good review and provides the necessary vocabulary and ability to use instruments for the following topics. About 10 hours.
   2. transducers such as the potentiometer for position measurement, thermistor, thermocouple, integrated circuit temperature sensors (e.g., Analog Devices AD590), photodiode, phototransistor, CdS cell, Si solar cell, etc. Hands on work with lab activities the teachers can take to their classroom. About 15 hours.
   3. digital integrated circuits with lab activities the teachers can take to their classroom. Highly recommend use of the large breadboarding sockets for circuit construction. About 30 to 40 hours.
   4. operational amplifier integrated circuits with applications to conditioning the signals from transducers (amplification, voltage to current conversion, offsetting, adding, filtering). Again constructing circuits on breadboarding sockets. Again with lab activities the teachers can take to their classroom. About 20 to 30 hours.
   5. construction of one or more instruments including making a printed circuit board (e.g., with Radio Shack materials), drilling necessary holes in chassis, soldering, assembly, debugging, and calibration. Suggested instruments include: general purpose IC based amplifier, IC based signal generator, triple power supply (+&- 12V and +5V), 4 digit timer, etc.

IT IS RECOMMENDED that any such institute also have a follow-up, to assist participants in implementing the activities in their classrooms.

G. **The Project as a Whole**

Participants who had taken part in all portions of the project were asked to evaluate its impact on them and their students. In addition, the highschool staff for the Concepts Institute were asked to evaluate the impact of the project on them and their students and colleagues. Thirteen participants from the 1985-1986 cycle evaluated the whole project, and 7 from the 1986-1987 cycle. Of group I, 11 gave the project as a whole an A grade, and 2 a B. For group II, 6 gave the project an A grade and 1 a B. For both groups, 19 of 20 said that as a result of the project, they were using more and different types of demonstrations in class; 18 of 20 use more and different types of labs; 17 of 20 put more emphasis on conceptual understanding and used different methods of teaching it; and 17 of 20 reported an increased use of electronics and computers in their classes. Participants felt their understanding had improved: in the area of concepts, 19 of 20 reported improved understanding; in use of shop tools and electrical measuring instruments, 17 of 20 reported improvement; and in both electronics and computer use, 20 of 20 reported improved understanding. In comments, many participants cited the value of knowing and feeling comfortable with university faculty.

"... getting to know some of the faculty here has been very helpful; I feel I have an excellent resource here and feel very comfortable with calling or writing for assistance if I need it."

"... I know some college people well enough to be able to call on them if I need help about something."

"The fact that you provide help and support in the way of advice, equipment, and answering questions has been invaluable."

Participants were also asked what had motivated them to apply to Project ARCHIMEDES, in order of importance. The most important factors for those responding were graduate credit and the materials used, followed closely by the availability of stipends and of an M. Ed. in Physics program. Several cited other reasons as most important: to be a better teacher, to prepare for new teaching assignment, recommended by fellow teacher, need to renew science background. One participant had applied "to learn more about physics than I knew before (which was very little), to overcome 'physics phobia', and to prove to myself that I wasn't as dumb as I thought I was".

Asked what other activities the department could engage in to help teachers, 6 participants responded that a continuation and expansion of the institutes would be desirable. Four participants wondered if there were some way the Department of Physics and Astronomy could be responsible for teaching the methods courses teachers traditionally take. We interpret this response as an endorsement of the utility of the methods and materials developed by the University of Washington Physics Education Research Group.

The 5 highschool staff members also indicated they were using more demonstrations and labs in their classes, and that they were more aware of misconceptions and tried to remediate them using hands-on activities. Two staff members had given workshops for elementary and middle school teachers in their districts; 2 other staff planned to conduct workshops in the near future.

Asked to comment on the impact of the project, the highschool staff produced a variety of responses. Several commented on the increase in understanding of concepts that had resulted, and indicated that both they and their colleagues were more aware of the problem of misconceptions in their students. One commented in particular on a participant (middle school teacher) from his school district whom he had assisted during the academic year following her participation in the Concepts Institute. She had developed much more confidence

and had decreased the anxiety she had previously exhibited in using hands-on activities. She was particularly sensitive to anxieties and misconceptions in the classroom. Her students developed a very positive attitude towards physical science and a not unreasonable level of understanding of the concepts. Another commented that a colleague from his school had taken the Concepts Institute and found it extremely useful in teaching physical science. The colleague stated to the staff member that she would now be more at ease in teaching physics concepts to her students and would not be afraid to let them do some hands-on work.

In summary, on the whole Project ARCHIMEDES achieved its goals for all but 4 of its participants. The participants suggested some changes for future versions, but mostly of a minor nature. We agree strongly with the participants who suggested that the Skills Institute should have had a follow-up.

V. PARTICIPANT ACTIVITIES EXTENDING THE IMPACT OF THE PROJECT

Four of the highschool staff members have conducted workshops in their school districts for elementary and middle school teachers. Fifty-two of the participants in the Concepts Institute have adapted activities from the University of Washington materials for their classes. Two participants have written an instructional module for middle school students based on the hands-on approach to developing concepts that they were introduced to in ARCHIMEDES. The module, **Mixed-Up Mixtures**, was written for a chautauqua course and is to be published by the National Science Foundation. One of these participants is working toward a doctoral degree in the School of Education at the University of North Carolina at Greensboro. Her dissertation involves writing and testing more conceptually-oriented hands-on modules.

Appendix I. Brochures and Application Forms

PROJECT ARCHIMEDES

Application Form: First Cycle (June, 1985 - August, 1986)

Application forms for the second cycle of activities (June, 1986 - August, 1987) will be mailed in February, 1986. All information submitted as part of this application will be kept confidential. Statistical data from the group of applications, without names attached, may be used in papers or reports to funding agencies.

1. Name: _____

   School Address: _____

   Home Address: _____

   Telephone: (School) _____ (Home) _____
   area number area number

2. Please indicate, in order of preference, all activities for which you wish to apply. Those wishing to audit should consult their Staff Development Officer about CEUs.

AUDIT	CREDIT	
		Summer Concepts Institute (NSF funded; June 17-July 26, '85; M-F, 9am-3pm)
_____	_____	In-service Followup Course (NSF funded; Aug. '85-May '86; 2 hr-TBA,biweekly)
		Physical Science Problem-Solving Skills Course (Not NSF funded)
_____	_____	(Aug. '85 - May '86; Th, 5-8 pm)
		Physics Problem-Solving Skills Course (Not NSF funded)
_____	_____	(Aug. '85 - May '86; Th, 5-8 pm)
		Summer Practical Skills Institute (NSF funded)
_____	_____	(June - July '86; M-F, 9 am - 3 pm)

3. Please indicate your professional standing (year achieved):

	phys. science	physics	science	chemistry	biology	math	other (what?)
certified							
endorsed							
provisional							

4. How many teachers at your school, including you, teach phys. science____physics____?

5. Please include with this application:
   a) a statement of degrees held (year, subject); teaching experience (subject, grade, years taught); other relevant experience (eg, workshops: subject, year)
   b) a brief statement of how the activities applied for will help you meet teaching goals (include any reasons you especially need these activities)
   c) a letter of recommendation from your principal or science supervisor
   d) a statement from an appropriate official indicating whether your school system will provide $250 for tools for your school if you are accepted into the Skills Institute. (See reverse of application for more information.)

RETURN by March 25, 1985, to: BOB MUIR, Physics Dept., UNC-G, Greensboro, NC 27412.

NOTIFICATION of status of applications will be sent by April 8, 1985.

PRACTICAL SKILLS INSTITUTE

Funding from the National Science Foundation provides supplies for this Institute. Participants will use the supplies to make equipment which will be taken back to their schools, to become the schools' property. Making the equipment requires the use of simple hand tools such as screwdriver, soldering iron, etc. The school system of each applicant accepted into this institute is being requested to provide $250 for the tools; they will be used in the Institute and be taken back to the schools to become the property of the schools. (The physics or physical science teacher should have first priority on their use.)

A tentative list of tools to be purchased follows. Items ordered will be adjusted so that total cost is $250 or less.

44-Piece Tool Box Kit (#3119, p13)*.....	$115.00
Contents: Soldering Pencil (Weller WP25-3)	
Solder (1 lb.)	
Solder aid, brush/fork	
Solder braids, 5 sizes	
6" Long nose pliers with side cutter	
5" Diagonal cutters	
Miniature cutters, 4"	
Miniature chain nose pliers, 4"	
Wire Stripper/cutter with adj. stop	
Slip joint pliers	
Tweezers, reverse action	
Precision knife with blades	
Hammer, ball peen, 4 oz. head	
Pocket scribe	
Rule, 6" stainless with wire gauge	
Calculator, inch-metric	
Nutdrivers, 3/16", 1/4", 5/16"	
Screwdrivers:	
slotted-3/32"x2", 1/8"x4", 3/16"x4", 1/4"x4", 5/16"x6"	
Phillips-#0x2", #1x3", #2x4"	
Hex key set, long arm-10 pcs.	
Reamer	
Adjustable wrench (6")	
Metal tool box with 1-3/8" deep lift-out tray, inside dimensions: 19"x6"x7-1/2"	
Digital Multimeter, 3-1/2 digit (Beckman DM45, p. c2)*.....	90.00
Banana leads (assortment)**.....	40.00
SHIPPING.....	3.00
SALES TAX.....	11.03
TOTAL.....	$259.03

*Contact East 1983/84 Catalog

**Assortment of 30 leads. Sizes: 9", 12", 18", 24". To be constructed from stacking banana plugs and lead wire available from Mouser Electronics, p. 45.

PROJECT ARCHIMEDES

Application Form: CONCEPTS INSTITUTE & FOLLOWUP (June 16 through July 25, 1986)

Application forms for the second offering of the SKILLS INSTITUTE (June, 1987 - August, 1987) will be mailed in February, 1987. All information submitted as part of this application will be kept confidential. Statistical data from the group of applications, without names attached, may be used in papers or reports to funding agencies.

1. Name: _____

   School Address: _____

   Home Address: _____

   Telephone: (School) _____ (Home) _____
   area number area number

2. I wish to apply for admission to the CONCEPTS INSTITUTE & FOLLOWUP for
   _____ Graduate Credit (6 hrs) _____ Audit (I will consult my Staff Development Officer about CEUs)

   The institute schedule is June 16 through July 25; M through F, 9am - 3pm.

3. Please indicate your professional standing (year achieved):

	phys. sci.	physics	science	chemistry	biology	math	other (what?)
certified							
endorsed							
provisional							

4. How many teachers at your school, including you, teach phys. sci. ____ physics ____?

5. Please include with this application:
   a) a resume which includes degrees held (year, subject); teaching experience (subjects, grades, years each was taught); other relevant experience (e.g., workshops: subject, year; etc.);
   b) a brief statement of how the activities of the CONCEPTS INSTITUTE & FOLLOWUP will help you meet teaching goals (include any reasons you especially need these activities);
   c) a recommendation from your principal or science supervisor;

COMPLETE application materials must be RECEIVED by March 24, 1986.
Send to: BOB MUIR, Physics Dept., UNC-G, Greensboro, NC 27412.
If you have questions, call the Physics Department: (919) 379-5844 or 379-5669.

NOTIFICATION of acceptance will be mailed by April 4, 1986.

PROJECT ARCHIMEDES

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   b) a brief statement of how the activities of the SKILLS INSTITUTE will help you meet teaching goals (include any reasons you especially need these activities);
   c) a recommendation from your principal or science supervisor;
   d) a statement from an appropriate official indicating that
      1) $250 will be provided by your school (or school system) for tools for your classroom (also to be used in the institute) if you are accepted into the SKILLS INSTITUTE. (See reverse of this form for more information.)
      2) your school will accept the donation of a microcomputer system to be used in your classroom, and that they will assure that appropriate support and maintenance will be provided so that it will be used to enhance the learning of your science students.

COMPLETE application materials must be RECEIVED by March 24, 1986.
Send to: BOB MUIR, Physics Dept., UNC-G, Greensboro, NC 27412.
If you have questions, call the Physics Department: (919) 379-5844 or 379-5669.

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6" Long nose pliers with side cutter	
5" Diagonal cutters	
Miniature cutters, 4"	
Miniature chain nose pliers, 4"	
Wire Stripper/cutter with adj. stop	
Slip joint pliers	
Tweezers, reverse action	
Precision knife with blades	
Hammer, ball peen, 4 oz. head	
Pocket scribe	
Rule, 6" stainless with wire gauge	
Calculator, inch-metric	
Nutdrivers, 3/16", 1/4", 5/16"	
Screwdrivers:	
slotted-3/32"x2", 1/8"x4", 3/16"x4", 1/4"x4", 5/16"x6"	
Phillips-#0x2", #1x3", #2x4"	
Hex key set, long arm-10 pcs.	
Reamer	
Adjustable wrench (6")	
Metal tool box with 1-3/8" deep lift-out tray, inside dimensions: 19"x6"x7-1/2"	
Digital Multimeter, 3-1/2 digit (Beckman DM45, p. c2)*.....	90.00
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TOTAL.....	$259.03

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**Assortment of 30 leads. Sizes: 9", 12", 18", 24". To be constructed from stacking banana plugs and lead wire available from Mouser Electronics, p. 45.

THE UNIVERSITY OF NORTH CAROLINA
AT GREENSBORO

Department of Physics and Astronomy

January 2, 1987

To Potential Applicants:

In the summer of 1987, we plan to offer both the Summer Skills Institute and a small section of the Summer Concepts Institute. Fellowships, travel costs, and texts will be provided for both institutes.

The NSF funding for Project ARCHIMEDES institutes and courses expires at the end of this summer. The In-service Follow-up Course and any Summer Institutes which might be offered after the summer of 1987 can only be offered as regular academic courses. This change means they will be offered only upon sufficient demand and that we will have to charge tuition and will not be able to provide fellowships, travel costs, nor texts. Because of this change, participants in the Summer Concepts Institute in 1987 will not be required to enroll in the In-service Follow-up.

Enclosed are application forms for both Institutes: Please apply for one only: either the Concepts Institute or the Skills Institute. Twenty-five fellowships are available; we expect approximately 5-8 of these to be for the Concepts Institute. We will notify you as soon as possible after the deadline date about the status of your application.

Sincerely yours,

Suzanne Lea Robert Muir Gaylord Hageseth

GREENSBORO, NORTH CAROLINA / 27412-5001

PROJECT ARCHIMEDES

Application Form: CONCEPTS INSTITUTE (June 15 through July 24, 1987)

All information submitted as part of this application will be kept confidential. Statistical data from the group of applications, without names attached, may be used in papers or reports to funding agencies.

1. Name: _____

School Name, Address: _____

_____

Home Address: _____

Telephone: (School) _____ (Home) _____
area number area number

2. I wish to apply for admission to the CONCEPTS INSTITUTE for
___ Graduate Credit (6 hrs) ___ Audit (I will contact my Staff Development Officer about CEUs)

The Institute schedule is June 15 through July 24, M through F, 9 am - 3 pm.

3. Please indicate your professional standing (year achieved):

	phys. sci.	physics	science	chemistry	biology	math	other (what?)
certified							
endorsed							
provisional							

4. How many teachers at your school, including you, teach phys. sci. ____ physics ___?

5. Please include with this application:
   a) a resume which includes degrees held (year, subject), teaching experience (subjects, grades, years each was taught), and other relevant experience (e.g., workshops: subject, year; etc.);
   b) a brief statement of how the activities of the CONCEPTS INSTITUTE will help you meet your teaching goals (include any reasons you especially need these activities);
   c) a recommendation from your principal or science supervisor.

COMPLETE application materials must be RECEIVED by March 9, 1987.
Send to: SUE LEA, Physics Dept., UNCG, Greensboro, NC 27412-5001
If you have questions, call the Physics Department: (919) 334-5844 or 334-5669.

NOTIFICATION of acceptance will be mailed on or before March 19, 1987.

PROJECT ARCHIMEDES

Application Form: SKILLS INSTITUTE (June 15 through July 24, 1987)

All information submitted as part of this application will be kept confidential. Statistical data from the group of applications, without names attached, may be used in papers or reports to funding agencies.

1. Name: _____

School Name, Address: _____

_____

Home Address: _____

Telephone: (School) _____ (Home) _____
area number area number

2. I wish to apply for admission to the SKILLS INSTITUTE for
___ Graduate Credit (6 hrs) ___ Audit (I will consult my Staff Development Officer about CEUs)

The Institute schedule is June 15 through July 24, M through F, 9 am - 3 pm.

3. Please indicate your professional standing (year achieved):

	phys. sci.	physics	science	chemistry	biology	math	other (what?)
certified							
endorsed							
provisional							

4. How many teachers at your school, including you, teach phys. sci. ____ physics ___?

5. Please include with this application:
   a) a resume which includes degrees held (year, subject), teaching experience (subjects, grades, years each was taught), and other relevant experience (e.g., workshops: subject, year; etc.);
   b) a brief statement of how the SKILLS INSTITUTE will help you meet your teaching goals (include any reasons you especially need these activities);
   c) a recommendation from your principal or science supervisor;
   d) a statement from an appropriate official indicating that
      1) $250 will be provided by your school (or school system) for tools for your classroom (also to be used in the Institute) if you are accepted into the SKILLS INSTITUTE. (See reverse side for more information.)
      2) IF we are successful in obtaining microcomputers to loan (we consider this unlikely at this point), your school must accept the loan of a microcomputer system to be used in your classroom and they must assure that appropriate support and maintenance will be provided to use it to enhance the learning of your science students. (See enclosed form.)

COMPLETE application materials must be RECEIVED by March 9, 1987.
Send to: BOB MUIR, Physics Dept., UNCG, Greensboro, NC 27412-5001
If you have questions, call the Physics Department: (919) 334-5844 or 334-5669.
NOTIFICATION of acceptance will be mailed on or before March 19, 1987.

PRACTICAL SKILLS INSTITUTE

Funding from the National Science Foundation provides supplies for this Institute. Participants will use the supplies to make equipment which will be taken back to their schools, to become the schools' property. Making the equipment requires the use of simple hand tools such as screwdriver, soldering iron, etc. The school system of each applicant accepted into this institute is being requested to provide $250 for the tools; they will be used in the Institute and be taken back to the schools to become the property of the schools. (The physics or physical science teacher should have first priority on their use.)

A tentative list of tools to be purchased follows. Items ordered will be adjusted so that total cost is $250 or less.

44-Piece Tool Box Kit (#3119, p13)*..... $115.00

Contents:
- Soldering Pencil (Weller WP25-3)
- Solder (1 lb.)
- Solder aid, brush/fork
- Solder braids, 5 sizes
- 6" Long nose pliers with side cutter
- 5" Diagonal cutters
- Miniature cutters, 4"
- Miniature chain nose pliers, 4"
- Wire Stripper/cutter with adj. stop
- Slip joint pliers
- Tweezers, reverse action
- Precision knife with blades
- Hammer, ball peen, 4 oz. head
- Pocket scribe
- Rule, 6" stainless with wire gauge
- Calculator, inch-metric
- Nutdrivers, 3/16", 1/4", 5/16"
- Screwdrivers:
  - slotted-3/32"x2", 1/8"x4", 3/16"x4", 1/4"x4", 5/16"x6"
  - Phillips-#0x2", #1x3", #2x4"
- Hex key set, long arm-10 pcs.
- Reamer
- Adjustable wrench (6")
- Metal tool box with 1-3/8" deep lift-out tray, inside dimensions: 19"x6"x7-1/2"

Digital Multimeter, 3-1/2 digit (Beckman DM45, p. c2)*.....	90.00
Banana leads (assortment)**.....	40.00
SHIPPING.....	3.00
SALES TAX.....	11.03
TOTAL.....	$259.03

*Contact East 1983/84 Catalog

**Assortment of 30 leads. Sizes: 9", 12", 18", 24". To be constructed from stacking banana plugs and lead wire available from Mouser Electronics, p. 45.

Appendix II. List of Presentations on Project ARCHIMEDES

Hageseth, G. T., Lea, S. M., and Muir, R. B. "Performance of Physics Teachers Enrolled in a Calculus-based Physics Course for Advanced Placement Physics as Compared to Undergraduate Students Enrolled in the Regular Calculus-based Course". APS-AAPT, January, 1987.

Hageseth, G. T. "Physics Teacher Certification through a Retro-fit Program". APS-AAPT, January, 1988.

Lea, S. M., and Muir, R. B. "Kinematics Misconceptions". SACS-AAPT, Spring, 1985.

Lea, S. M., and Muir, R. B. "Project ARCHIMEDES: A Program for Highschool Teachers". SESAPS, Fall, 1985.

Lea, S. M., Muir, R. B., and Hageseth, G. T. "Student Misconceptions in a Course for Highschool Teachers". APS-AAPT, January, 1986.

Lea, S. M., and Muir, R. B. "Physics Misconceptions in a Course for Highschool and Middle-School Teachers". SESAPS, Fall, 1986.

Lea, S. M., Muir, R. B., and Hageseth, G. T. "Project ARCHIMEDES: Effects on the Highschool Classroom". APS-AAPT, January, 1987.

Lea, S. M. "Project ARCHIMEDES: How Elementary School Teachers Understand Basic Physics Concepts". APS-AAPT, January, 1988. Also SACS-AAPT, Spring, 1988.

Muir, R. B. "A Summer Institute on Practical Skills for Highschool Teachers," APS-AAPT, January, 1986.

Muir, R. B., Hageseth, G. T., and Lea, S. M., "Project ARCHIMEDES: Electronics and Microcomputer Summer Institute for High School Teachers", APS-AAPT, January, 1987

Muir, R. B. "Project ARCHIMEDES: Summary Report on an Electronics and Microcomputer Summer Institute for High School Teachers", APS-AAPT, January, 1988

Muir, R. B. "Project ARCHIMEDES: Summary Report on an Electronics and Microcomputer Summer Institute for High School Teachers", SACS-AAPT, April, 1988

Muir, R. B., "A Summer Institute on Electronics and Microcomputers for High School Teachers of Science", Conference on Computers in Physics Instruction, NC State University, August, 1988.

Appendix III. Articles submitted to **The American Journal of Physics**